

The Global Hawk Unmanned Aerial Vehicle Acquisition Process

A Summary of Phase I Experience

**Geoffrey Sommer
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PREFACE

An important part of the process of improving acquisition management methods and policy is the accumulation of experience from ongoing or recently completed projects, especially those involving unusual situations or innovative acquisition policies. Such policies are being pursued in the High Altitude Endurance Unmanned Aerial Vehicle (HAE UAV) program, under the direction of DARPA (the Defense Advanced Research Projects Agency). Our objective in this study is to understand how the various innovations in acquisition management methods affect the program outcomes and how the lessons of these projects might be applied to a wider variety of projects to improve Department of Defense acquisition strategies.

This study was initiated in Fiscal Year 1994 and will continue through the first three phases of the program. A final report will be issued at the end, preceded by periodic interim reports. This is the first such interim report, covering Phase I of the Global Hawk segment of HAE UAV. This report should primarily interest Department of Defense officials concerned with weapon system acquisition procedures.

This research was carried out in the Acquisition and Technology Policy Center of RAND's National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense, the Joint Staff, and the defense agencies.

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SUMMARY

There is a long history of efforts to improve the efficiency and effectiveness of the weapon acquisition process, ranging from a succession of studies to specific actions undertaken on selected programs. The purpose of this case study is to understand how one such program, the High Altitude Endurance Unmanned Aerial Vehicle (HAE UAV), has benefited from certain changes in established acquisition procedures. It is hoped that conclusions can then be drawn regarding the suitability of these measures for the wider Department of Defense (DoD) acquisition environment.

The Defense Advanced Research Projects Agency (DARPA), in conjunction with the Defense Airborne Reconnaissance Office (DARO), is embarking on development of two unmanned air vehicles (UAVs): Tier II+ and Tier III-¹ UAV and tactical surveillance/reconnaissance programs have a history of failure due to inadequate integration of sensor, platform, and ground elements, together with unit costs far exceeding what the operator has been willing to pay. To overcome these historical problems, DARPA, with congressional support, is undertaking an innovative acquisition program that is different from normal DoD acquisition efforts in several important ways:

- The approach gives flexibility to depart from acquisition-specific law and related regulations.
- Contractors do not have to meet a wide range of performance requirements. Instead, a firm cap of \$10 million has been placed on unit flyaway price, and the firms can trade all other performance goals as necessary to stay within that cap.
- The program has been designated an Advanced Concept Technology Demonstration (ACTD), i.e., a program intended to demonstrate mature or maturing technologies to warfighters in an accelerated fashion.
- Contractors, in collaboration with the government, must institute the forms and functions of integrated product and process development (IPPD), an approach intended to streamline program management within functional areas. (This stricture applied only to Tier II+.)

The challenge for the RAND study reported here is to quantify the distinct effects of each of these factors, while taking into account the effect of program-specific events and disturbances as they occur. The study was initiated in Fiscal Year 1994 and will continue through the first three phases of the program (up to start of production). A final report will be issued at the end, preceded by periodic interim reports. This is the first such interim report. It documents Phase I of the Tier II+ segment of HAE UAV and conveys the reactions of the contractors involved, which we learned through interviews. While it is too early to

¹After completion of Phase I, the Tier II+ program was renamed Global Hawk and Tier III- renamed Dark Star. In this report covering Phase I, the original nomenclature is used.

draw any conclusions as to the effectiveness of the various acquisition reforms applied to this program, contractor judgments regarding the process to date are of definite interest. The main points are these:

- **Acquisition Waivers.** Not unexpectedly, there was unanimity about the beneficial effects of the waivers, both in reducing the "barriers to entry" faced by the contractors and in increasing the efficiency of the program once under way. What was surprising was the freedom granted by corporate management to the respective Tier II+ teams, as a synergistic result. Uniformly, top management appreciated that "reinventing government" and reinventing corporate culture go hand in hand.
- **Price Cap.** All contractors felt that the \$10 million cap was reasonable and strongly supported the design-to-price philosophy. There was a divergence of opinion, however, on the relationship between technical risk and price risk.
- **ACTDs.** There is uniformly strong support for the concept of ACTDs, but concern about the future regarding the potential for added requirements, and regarding the possibility of a schedule disruption due to high concurrency of full engineering development and production.
- **IPPD.** In most cases, the contractors had previous favorable experience with IPPD and asserted that they would have adopted this approach in any event. However, the quality of the contributions by the Joint Program Office (JPO) to IPPD was more controversial because of problems stemming from the number of agreements awarded and from Phase I's competitive nature.

The most striking aspect of the Tier II+ Phase I contractor interviews was the wide agreement on most aspects of the program. Despite some forthright criticisms, which related mostly to specifics of program execution, there was universal support for what the JPO was trying to achieve. It is clear that each of the special features of the Tier II+ program played a key part in guiding the contractors' decisionmaking process, and it is also clear that the special features are heavily interrelated.

For the future, the level of agreement displayed by the Phase I contractors on the effects (or predicted effects) of the program's special features leads us to believe that the experiences of the winning contractor team will be more generalizable than would otherwise have been the case.

ACKNOWLEDGMENTS

We would like to acknowledge the invaluable assistance of the HAE UAV Joint Program Office, and specifically John Entzminger, Michael Kelley, Colonel Doug Carlson (USAF), Commander Roger Messersmith (USN), Lieutenant Colonel Keith Matthews (USAF), Tom Bucher, and George Weston. We are also indebted to Orbital Sciences Corporation, Aurora Flight Sciences, Northrop Grumman, Boeing, Raytheon, Westinghouse, Scaled Composites, Teledyne Ryan Aeronautical, and E-Systems, without whose gracious cooperation this report would not have been possible.

ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
ACTD	Advanced Concept Technology Demonstration
CAIV	Cost as an Independent Variable
CONV	Conventional (HAE UAV)
CINC	Commander in chief
CPFF	Cost Plus Fixed Fee
CPIF	Cost plus incentive fee
CR	Close range (UAV)
CY	Calendar year
DARPA	Defense Advanced Research Projects Agency
DARO	Defense Airborne Reconnaissance Office
DCAA	Defense Contract Auditing Agency
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
DODD	DoD Directive
DSB	Defense Science Board
DTC	Design to cost
DUSD/AT	Deputy Undersecretary of Defense, Advanced Technology
EFOG-M	Enhanced Fiber Optic Guided Missile
EO	Electro-optic
FAR	Federal Acquisition Regulation
FCA	Functional configuration audit
FFP	Firm fixed price
FTRR	Flight test readiness review
FY	Fiscal year
HAE UAV	High Altitude Endurance Unmanned Aerial Vehicle
HALE	High-altitude long-endurance (UAV)
IDR	Interim Design Review
IMP	Integrated Management Plan
IMS	Integrated Master Schedule
IPPD	Integrated product and process development
IPT	Integrated product team
IR	Infrared
JPO	Joint Program Office
JROC	Joint Requirements Oversight Council
JS	Joint Staff
J-STARS	Joint Surveillance and Target Attack Radar System
JTF	Joint task force

JWCA	Joint Warfare Capability Assessment
LADC	Lockheed Advanced Development Corporation
LO	Low observable
MAE UAV	Medium Altitude Endurance Unmanned Aerial Vehicle
MNS	Mission Need Statement
MOU	Memorandum of Understanding
MR	Medium range (UAV)
NRE	Nonrecurring engineering
OSD	Office of the Secretary of Defense
PCA	Physical configuration audit
PLSS	Precision Locator Strike System
PSS	Preliminary system specification
PSSR	Preliminary system specification review
P2DR	Phase II Design Review
RSTA	Reconnaissance, surveillance, and target acquisition
SAIC	Science Applications International Corporation
SAM	Surface-to-air missile
SAR	Synthetic aperture radar
SCD	System Capability Document
SIGINT	Signals intelligence
SOR	System objectives review
SR	Short range (UAV)
TBD	To be determined
TDD	Task Description Document
TINA	Truth in Negotiations Act
UAV	Unmanned Air Vehicle
UAV JPO	Unmanned Air Vehicle Joint Program Office
UFP	Unit flyaway price
USC	United States Code
USD(A&T)	Under Secretary of Defense for Acquisition and Technology
VCJCS	Vice Chairman of the Joint Chiefs of Staff
WPAFB	Wright Patterson Air Force Base

1. INTRODUCTION

There is a long history of efforts to improve the efficiency and effectiveness of the weapon acquisition process. The purpose of this case study is to understand how one such program, the High Altitude Endurance Unmanned Aerial Vehicle (HAE UAV), has benefited from certain changes in established acquisition procedures. It is hoped that conclusions can then be drawn regarding the suitability of these measures for the wider Department of Defense (DoD) acquisition environment.

The Defense Advanced Research Projects Agency (DARPA), in conjunction with the Defense Airborne Reconnaissance Office (DARO), is embarking on development of two unmanned air vehicles (UAVs): Tier II+ and Tier III-¹. These systems are intended to provide surveillance information to the warfighter. The programs respond to the recommendations of the Defense Science Board (DSB) and to the operational needs stated by DARO on behalf of the military service users. A successful development program should lead to follow-on procurements by one or more of the services if operational demonstrations indicate that military utility can be affordably achieved.

UAV and tactical surveillance/reconnaissance programs have a history of failure due to inadequate integration of sensor, platform, and ground elements, together with unit costs far exceeding what the operator has been willing to pay. All have contributed to a sense of frustration and a realization that DoD needs to explore ways to improve the acquisition process. To overcome these historical problems, DARPA, with congressional support, is embarking on an innovative acquisition program that is different from normal DoD acquisition procedures in several important ways.

First, the approach gives flexibility to depart from acquisition-specific law and related regulations. Contractors are encouraged to tailor or "reinvent" the acquisition system in ways especially suited to this particular program. The idea is to avoid rigid procurement practices, to encourage more use of commercial business practices and products, and to encourage firms to organize the project around integrated product teams (IPTs) rather than by functional discipline.

Second, contractors do not have to meet a wide range of performance goals. Past experience indicates that program cost goals have not been met because initial performance expectations were too demanding and constraining. That approach left little room for design trades in the critical, early program phases. In this program, the DARPA/DARO paradigm is to establish a firm cap of \$10 million on unit flyaway price, and let the firms trade all other performance goals as necessary to stay within that cap. Military capability will be determined through flight test and operational demonstrations, and the program will be terminated if the system does not provide adequate military utility.

¹After completion of Phase I, the Tier II+ program was renamed Global Hawk and Tier III- renamed Dark Star. In this report covering Phase I, the original nomenclature is used.

Finally, the HAE UAV program has been designated an Advanced Concept Technology Demonstration (ACTD), a program intended to demonstrate mature or maturing technologies to the warfighters in an accelerated fashion. This places a premium on early operational user involvement in the program and defines an aggressive program schedule, which in turn will tend to drive (and hopefully, limit) program nonrecurring engineering (NRE) costs.

The challenge for this study is to quantify the distinct effects of each of these factors, while taking into account the effect of program-specific events and disturbances as they occur. To do so, this RAND project, spanning several years, is organized into three tasks:

TASK 1: HISTORICAL UAV DATA COLLECTION AND BASELINING

In this portion of the research, which is ongoing, we are collecting and analyzing historical cost, schedule, and performance data from past comparable UAV programs. To date, we have found relatively little historical data preserved on these programs at a detailed level, which limits their value as a baseline for comparing with the current HAE UAV programs. We will continue to search various government and industry archives for such data, but it is unlikely that any such programs will provide a baseline suitable for direct comparison with the Tier II+ program. Therefore, using available data, we will attempt to create a synthetic version of the Tier II+ program as it might have been if standard acquisition doctrine, regulations, and procedures had been followed. This approach should enable us to make estimates of the overall effectiveness of the innovative acquisition methods used in the HAE UAV program.

TASK 2: HAE UAV TIER II+ CONTRACTOR PERFORMANCE

Working closely with the program office, we are collecting program data on each of the active contractors in the Tier II+ program as the data become available. We are also obtaining corresponding data on policy guidance and funding from the program office. In addition to documenting the program, we will attempt to determine the underlying causes of each major program event, especially events that represent changes from the original plan and expectations. During fiscal year (FY) 1995, a major effort was made to interview each of the contractors involved in Phase I of the Tier II+ program. These interviews, and related data collected from the program office, placed special emphasis on understanding how contractor actions and decisions, and the Phase I results, were affected by the special acquisition environment provided in the HAE UAV program.

Our plan was to conduct interviews with all five of the contractors funded for Phase I studies, selected Phase I subcontractors, and a representative unsuccessful Phase I bidder. The purposes of interviewing contractors that were unsuccessful in bidding for Phase I were to

- assist in hypothesis-building
- determine areas of consensus and disagreement
- elicit fruitful avenues for inquiry
- enable bias correction
- facilitate generalization beyond the successful contractor.

The following contractors were interviewed: Orbital Sciences Corporation, Westinghouse, Northrop Grumman, Scaled Composites, Raytheon, Boeing, Teledyne Ryan, E-Systems, and Aurora Flight Sciences.

It should be noted that the kind of tracking and data collection performed in this task requires the contractors' cooperation. Every effort has been made by RAND, and will continue to be made, to minimize demands placed on the contractors and the program office staffs, but some demands are inevitable. To date, excellent cooperation has been obtained from most of the Tier II+ contractors.

TASK 3: FINAL ANALYSIS

As the HAE UAV program draws to a close, we will pull together the information collected up to that point and present two kinds of overall results. One will be focused on comparisons between the HAE UAV program and other comparable programs. As mentioned above, the latter will include actual past programs and synthetic programs representing the probable form of the HAE UAV program had it been performed under standard acquisition procedures. This will provide an understanding of the strengths and weaknesses of the overall HAE UAV acquisition strategy. Second, we will interpret those results in terms of lessons that might be applied to future programs.

At this point in time, we are well short of the point where we can analyze program outcomes, but we can characterize some of the ways in which contractors have responded to the special provisions of the program. In this initial report on Phase I of the Tier II+ program, we first summarize the program structure in Section 2. Then in Section 3 we provide historical background on earlier UAV programs. In Section 4, we provide an expanded discussion of the special acquisition approach being used in the HAE UAV programs. Finally, in Section 5 we summarize results of our interviews with contractors. Supporting information is provided in three appendixes.

2. TIER II+ PROGRAM OVERVIEW

In this section, we provide a brief overview of the Tier II+ HAE UAV program to help the reader understand the contrasts in acquisition style that are discussed in subsequent sections.

The basic concept for the Tier II+ program calls for a system capable of overt, continuous, all-weather, day/night, wide-area reconnaissance and surveillance. The system is composed of three parts—an air vehicle segment, a ground segment, and a support segment. Only a few performance objectives were identified for the overall system. The flight vehicle was to be able to cruise to a target area 1,000 miles distant, loiter over the target area for 24 hours at an altitude of about 65,000 ft, and then return to the take-off point. A mission equipment package was defined to consist of a synthetic aperture radar (SAR) and/or an Electro-optic/Infrared (EO/IR) sensor, a data recorder subsystem, a threat warning receiver subsystem, and an airborne data link subsystem that would transmit data to the ground station that, in turn, would synthesize and display the sensor data.¹ Contrary to typical practice, those performance characteristics were not mandated; all were listed as goals that could be traded against the one system characteristic that was a firm requirement. That single dominant requirement was that the flight segment had to be produced at a unit flyaway price (UFP) not to exceed \$10 million (FY94 dollars) for the first production aircraft.² In fact, early in the program it was DARPA's opinion that the complete set of *all* performance objectives could probably not be packaged into a \$10 million UFP air vehicle. The contractor was to meet, or come close to meeting, as many as possible of the other system performance goals, but only the price limit was mandated. Where it was not possible to meet all performance goals, the contractor was to attempt a system design permitting an affordable and reasonable future growth path to reach all performance objectives. Ground and support segments, while not part of the UFP objective, had to be balanced in cost and capability. (For more on the Tier II+ mission and preliminary concept of operations, see Appendix A.)

The HAE UAV Tier II+ program consists of four phases, as depicted in Figure 1. Phase I, performed during 1994 and 1995, was a six-month competitive effort that defined the air vehicle, ground and support systems, and system interfaces sufficiently well to provide confidence in achieving the performance goals within the UFP cap. This phase resulted in a preliminary system specification, a system segment specification, and a proposed agreement to cover Phase II of the project.

¹While the solicitation provided the option of carrying either or both of the major sensor packages, the same section carried the statement "As an objective, the air vehicle will have sufficient capacity to carry all prime mission equipment simultaneously."

²The price cap was defined as applying to the cumulative average of production units 11 through 20, after an initial batch of 10 had been produced for developmental and operational tests and demonstrations.

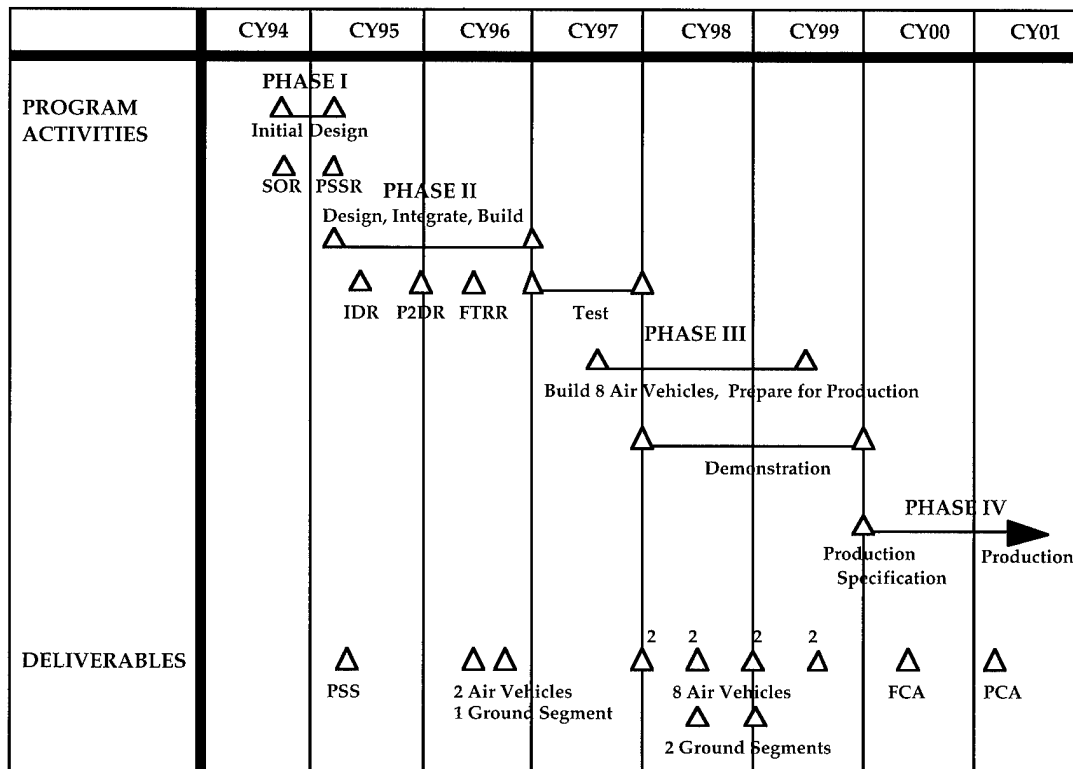


Figure 1—Tier II+ Program Schedule

The solicitation for Phase I, issued in April 1994, stated the intent to select three firms, each of which would receive an "agreement" funded at \$4 million. The funding was provided on a "not to exceed" basis, with payments based on successful completion of payable milestones identified in the solicitation.

Fourteen organizations, each consisting of a consortium of two or more firms, responded. Given the breadth and quality of the responses, DARPA selected five to perform the Phase I task. Those five were³

- Loral Systems Co. with Frontier Systems, Inc.
- Northrop Grumman Aerospace Corp. with Westinghouse Electric Corp.
- Orbital Sciences Corp. with Westinghouse Electric Corp.
- Raytheon Co. Missile Systems Division with Lockheed Advanced Development Co.
- Teledyne Ryan Aeronautical with E-Systems Corp.

During Phase I, DARPA revised its plans for Phase II, which called for building two flight vehicles, plus one ground and control segment, and supporting a system

³Only the principal airframe and electronic system members of the teams are listed here; most of the consortia included additional members that provided specialized services.

demonstration. Although DARPA had previously announced that two Phase II contractors were to be awarded funded agreements (and thus, two systems designed and flown), funding limitations forced a down-selection to only one Phase II contractor. This early elimination of competition within the Tier II+ program proved to be controversial, both within contractor circles and on Capitol Hill. The initial Tier II+ funding plan and the revised plan are presented together in Figure 2;⁴ note that these totals represent funds to be obligated to the contractors, not total funds available to the program, an early estimation of which is represented in Figure 3.⁵ The difference represents government administrative costs, including the costs of operational demonstrations, and government-furnished equipment.⁶

PHASE	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	TOTAL
PHASE I (2 Contractors) 5	12 20								12 20
PHASE II (2 Contractors) 1		75 40	110 80	50 38	6				235 164
PHASE III (1 Contractor)				75 55	130 94	50 99	20 0		275 248
PHASE IV (One Contractor)						TBD	TBD	TBD	TBD

Figure 2—Tier II+ Program Obligation Plan (in then-year millions of dollars)

⁴Original figures are from the draft Tier II+ solicitation dated 29 April 1994. The release version of the solicitation (ARPA PS 94-33) dated 1 June 1994 had a funding profile that was smaller by \$10 million: \$70 million instead of \$75 million in both FY95 and Phase III of FY97 (not reflected in this figure). The revised numbers shown are from the Tier II+ Phase II solicitation, dated 15 February 1995.

⁵Tier II+ budget line includes common ground segment, miscellaneous support, government-furnished equipment, studies, and the Phase III demonstration costs for both Tier II+ and Tier III-. These figures are from *High Altitude Endurance Unmanned Aerial Vehicle Systems—Program Briefing for Joint Requirements Oversight Council*, 8 November 1994, and are also found in a different format in the HAE UAV ACTD Management Plan draft version 1.0, dated 15 December 1994. Revised totals are from a Joint Program Office briefing to the Association for Unmanned Vehicle Systems conference in Washington, D.C., on 11 July 1995—FY breakdown is unavailable.

⁶Note that the program assumed standard OSD inflation indices in converting between then-year and FY94 budget year dollars: FY94 2.2, FY95 5.2, FY96 8.3, FY97 11.5, FY98 14.9, FY99 18.3, FY00 21.9 (%).

PROGRAM	FY94	FY95	FY96	FY97	FY98	FY99	FY00	FY01	TOTAL
TIER II+	23	82	140	150	150	150	TBD	TBD	695 676
TIER III-	30	62	50	45	15	15	TBD	TBD	217 226
TOTAL	53	144	190	195	165	165	TBD	TBD	912 902

Figure 3—HAE UAV Program Funding (in then-year millions of dollars)

As tentatively set out in the solicitation for Phase II, DARPA's evaluation of the five contractor proposals was to address the product capability, program structure, and cost presented in each. It was anticipated that the following criteria would be used (for more details, see Appendix B):

- Whether technical, management, and cost practices were sound and whether the costs presented appeared complete and realistic.
- Whether offerors comprehended the scope of the effort and the program objectives.
- How close the proposal came to meeting all performance objectives within the UFP limit.
- How likely the contractor was to successfully execute Phase II based on performance to date.

In February 1995, the evaluation protocol was revised to encompass four areas, defined as follows (for more details, see Appendix C):

- *System capability:* How close is the proposed system to meeting the System Capability Document (SCD) objectives? How effective and suitable will the final system be, as a whole, in the operational environment? How stable is the proposed design and technical approach throughout the phases of the program? How well does the system design support growth and flexibility? (All these questions were addressed within the context of the \$10 million UFP.)
- *Technical approach:* Is the technical approach low-risk and has the use of off-the-shelf technology been maximized? Does the technical approach and Integrated Master Plan (IMP) encompass the entire system? Is the design, development, and manufacturing approach adequate for each phase of the program? Are the technical processes described in the Process IMP adequate for their intended use?

- *Management approach:* Does the IMP depict a well-planned program that can be easily tracked? Does it propose a system that can be delivered within the resources provided? (Specific management functions evaluated included planning, processes, program control, and organization; past performance was also evaluated.)
- *Financial approach:* Will the offeror be able to execute the proposed program within the financial resources proposed? Are those resources consistent with the UFP? (Specific criteria were reasonableness, realism, and completeness of cost estimates.)

The Teledyne Ryan team won the Tier II+ Phase II award in May 1995. An illustration of the successful Teledyne Ryan air vehicle design is presented in Figure 4. Phase II consists of designing and building two complete air vehicles (including payloads) and one ground segment, together with flight tests sufficient to demonstrate technical performance and provide continuing confidence in future ability to meet the UFP limit. This phase was originally expected to take 27 months, but 6 months were added to the Phase II flight test schedule by agreement with the contractor. Phase II is being conducted using an updated agreement from Phase I with a cost-type payment arrangement. A successful end to Phase II will be a "thumbs-up" by the user to continue and a system specification that all participants believe will lead to the \$10 million UFP.

In Phase III, the Teledyne Ryan team is to build up to eight additional air vehicles, two additional ground segments, and support a two-year field demonstration of operational capabilities. Phase III management will transition to a joint service organization to be located in the Air Force Aeronautical Systems Center at Wright Patterson Air Force Base (WPAFB), and headed by the Air Force. The objective of Phase III is a successful operational demonstration and completion of all tasks that will enable the \$10 million UFP to be achieved in Phase IV. Phase III will take approximately 30 months and will be conducted under an updated DARPA agreement.

Prior to entering Phase III, it is intended that Teledyne Ryan will make an "irrevocable" offer of 10 air vehicles in Phase IV (beyond the 10 already built) for a UFP of \$10 million (FY94 dollars).

Presuming successful completion of Phases II and III, Phase IV will consist of serial production necessary to meet operational needs.

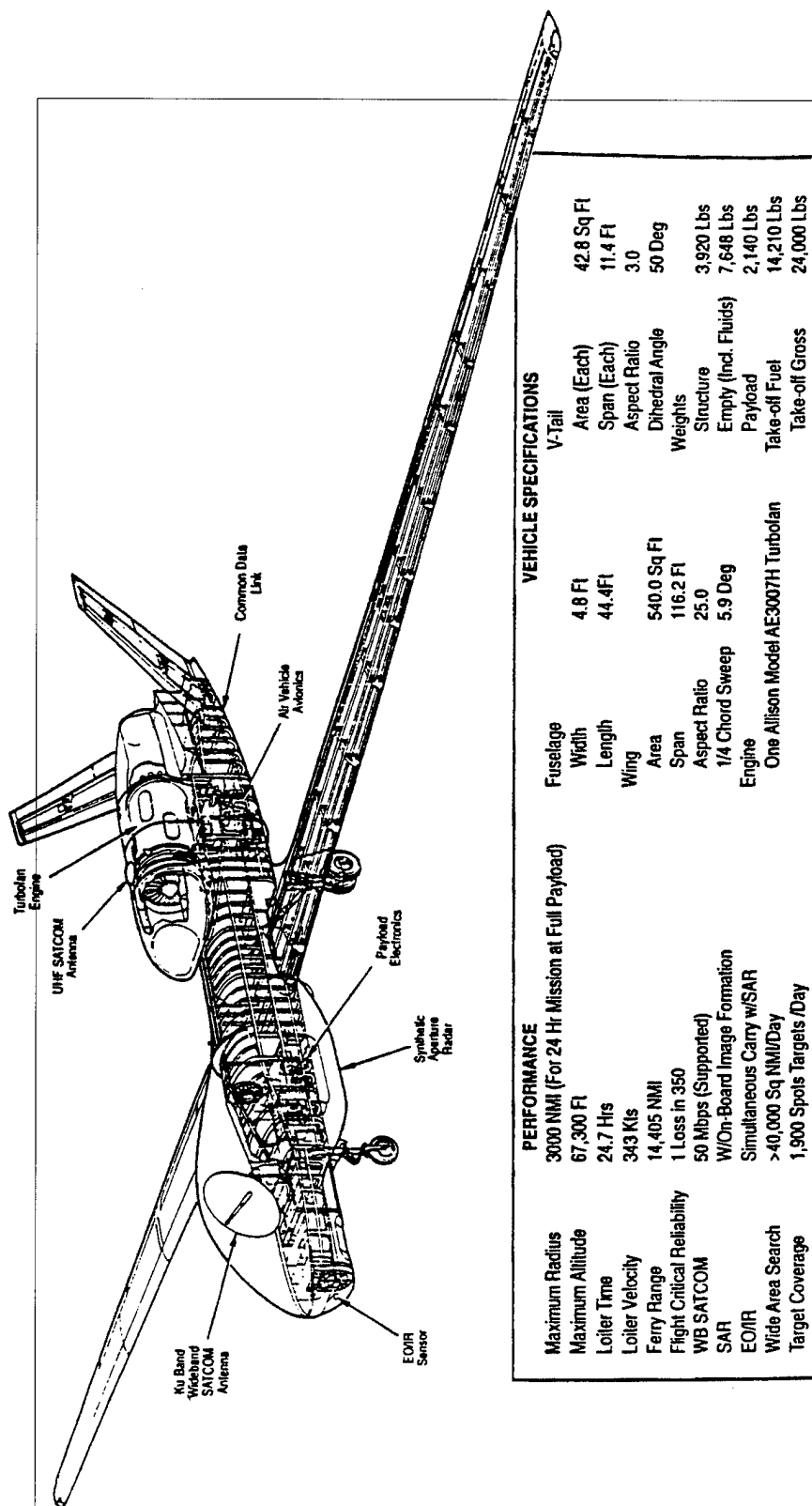


Figure 4—Teledyne Ryan Tier II+ UAV

Figure 4—Teledyne Ryan Tier II+ UAV

3. BACKGROUND ON UAV PROGRAMS IN THE UNITED STATES

In this section, we present background information on U.S. experience with UAVs. A brief description of the difficulties experienced in those programs will help to set the stage for the discussion of acquisition innovations presented in the following section.

THE UAV: PROMISE UNFULFILLED

It is important to place the HAE UAV program in the context of past UAV acquisition experience, because the effects of the unique features of this program may depend to some extent on its being a UAV program. For example, cost, schedule, performance, and risk trade-offs may, or may not, have been different for a manned aircraft system.

Historically, UAV programs in the United States have been bedeviled by cost growth, schedule slippage, manifold technical deficiencies during protracted development, and generally disappointing operational results. Notorious examples include the U.S. Army's Lockheed *Aquila* UAV program, which was canceled in the late 1980s¹ and the Teledyne Ryan BQM-145A Medium Range UAV,² which was canceled in October 1993. Both programs suffered from performance/technical problems and substantial cost growth. Overseas, however, experience with UAVs has sometimes been very good. A case in point is Israel's excellent results employing *Scout* and *Mastiff* UAVs against Syrian air defenses in the Bekaa valley in Lebanon during 1982.³ The Syrians lost 19 surface-to-air missile (SAM) batteries and 86 combat aircraft, essentially a complete air defense system, and the Israeli UAVs played a pivotal role in this accomplishment. Thus, it is generally acknowledged that U.S. UAVs have suffered from flaws in execution rather than concept. Nevertheless, high-level support for UAVs persists, and a strong motivation exists to overcome the programmatic and technical difficulties experienced to date.

The cause of the poor track record of UAV programs in the United States is not entirely clear. Certainly, the mere fact of their being *unmanned* vehicles cannot be the cause. After all, the United States has had great success with other unmanned systems, ranging from interplanetary spacecraft and satellites to cruise missiles and submersibles. What, then, makes UAVs unique? A possible explanation is that UAVs in general have never had the degree of operational user support necessary to allow their procurement in sufficient quantities (perhaps because of funding competition from incumbent programs, or because of the conjectural nature of their capabilities). Thus, the learning curve is never ascended, multiple failures occur, risk tolerance decreases, unit costs rise as a result, and user support decreases yet further in a diminishing spiral. There are historical precedents for this type of

¹*Aquila Remotely Piloted Vehicle—Its Potential Battlefield Contribution Still in Doubt*, General Accounting Office, GAO/NSIAD-88-19, October 1987.

²*Unmanned Aerial Vehicles—Medium Range System Components Do Not Fit*, General Accounting Office, GAO/NSIAD-91-2, March 1991.

³Air Chief Marshal Sir Michael Armitage, *Unmanned Aircraft*, 1988, p. 85.

technology failure. The risk of UAV program failure may also have been compounded by three other factors:

- Expectations of low cost (stemming from the “model airplane” heritage of UAVs).
- A flight safety dichotomy (UAVs need not be “man-rated,” but range-safety and redundancy considerations tend to increase costs).
- The variable and unpredictable nature of the aerial environment itself (compared to the more predictable oceanic or space environments).

For the purposes of this study, there are two main cautions deriving from the above. Firstly, the success of UAV programs can be expected to be highly dependent on levels of operational user support. Secondly, near-term UAV programs may need to be structured in a more risk-averse form than is commonly appreciated. These factors have to be taken into account when considering the effect of the acquisition streamlining and other features applied to the HAE UAV program.

THE UAV IN THE UNITED STATES THROUGH 1993

In the United States, the first large-scale use of nonlethal UAVs occurred during the Vietnam War, when air-launched Teledyne Ryan UAVs were employed on reconnaissance missions over North Vietnam. Although loss rates were fairly high—attrition of UAVs was preferable to that of manned aircraft—useful imagery was recovered, and some UAVs survived for many missions over hostile territory. Of course, the wartime imperative and high production rates resulted in a relatively steep learning curve and consequent reductions in procurement cost.

Efforts were then undertaken to expand the Teledyne Ryan family of UAVs (or drones or Remotely Piloted Vehicles as they were then known) to include high-altitude, long-endurance (HALE) variants. A program known as *Compass Arrow* (AQM-91A) was pursued in the 1960s, resulting in an ultra-high-altitude (80,000 ft) surveillance aircraft that was, unfortunately, very expensive. The *Compass Arrow* program was terminated in the early 1970s after 28 aircraft had been produced but before they became operational, as a result of U.S. rapprochement with China (their primary strategic target).⁴ *Compass Arrow* was followed by the *Compass Cope* program of the 1970s, which was intended to develop a reconnaissance and signals intelligence (SIGINT) HALE UAV. Boeing and Teledyne Ryan competed in a protracted development and fly-off program, marred by a crash of one of the Boeing aircraft. The program was ultimately terminated, largely because of a weakness in operational requirements justification. It did not help that a key potential payload, the Precision Locator Strike System (PLSS) was also slated for installation on the manned U-2.⁵ (This competition between manned and unmanned airborne reconnaissance options continues to the present day.)

⁴A *History of Teledyne Ryan Aeronautical, Its Aircraft and UAVs*, Teledyne Ryan corporate brochure, p. 8; and unpublished RAND research by John F. Schank on cost-estimating relationships for airframes of remotely piloted vehicles.

⁵*The RPV/Drones/Targets Market 1975-1985*, DMS Incorporated, 1975, pp. II-37 to II-40.

The 1980s saw a flowering of smaller, tactical UAV programs in the United States. The successes of the Israelis served as a powerful impetus, and the *Scout* was modified and sold to the United States as the *Pioneer*. It quickly became apparent, however, that there was an operational justification for UAVs with improved capabilities, and several companies met the challenge with new creations. One such program was the Lockheed *Aquila*, which was to become notorious for its management failures and cost overruns.⁶

In FY88, Congress directed the consolidation of DoD nonlethal UAV program management. There was a perception that multiple, redundant UAV programs were being pursued by DoD, and an integrated management structure was therefore necessary. The UAV Joint Project Office (UAV JPO) was formed and embarked upon a four-element UAV program in response to several approved Mission Need Statements (MNSs).⁷ Among these was one approved by the Joint Requirements Oversight Council (JROC) in January 1990 to establish a "Long Endurance Reconnaissance, Surveillance, and Target Acquisition (RSTA) Capability." The intent was to provide warfighting commanders in chief (CINCs) with a capability to conduct wide-area, near-real-time RSTA, command and control, SIGINT, electronic warfare, and special operations missions during peacetime and all levels of war. This capability was to be exercisable against defended and denied areas over extended periods of time.⁸

The four core UAV programs were the close range (CR), short range (SR), medium range (MR) and endurance UAVs. The UAV JPO suffered an embarrassing reversal with the cancellation of the core Medium Range UAV in October 1993. The remaining programs were reorganized into two groups: the Joint Tactical Program (absorbing the CR and SR) and the Endurance Program.⁹

In July 1993, the JROC had endorsed a three-tier approach to acquiring an "endurance" capability:

- Tier I Quick Reaction Capability
- Tier II Medium Altitude Endurance
- Tier III "Full Satisfaction" of the MNS.

Tier I and Tier II were implemented as the *Gnat 750* and *Predator* UAVs. In July 1993, the Deep Target Surveillance/Reconnaissance Alternatives Study (or "Summer Study") was launched by the DSB to address the Tier III requirement. The Summer Study focused on imagery support to military operations but concluded that existing potential Tier III programs were either too expensive or unable to adequately satisfy the requirement. At this point, DARO substituted the parallel Tier II+/Tier III- approach for Tier III, meeting that requirement with a high/low force mix of complementary systems. Tier II+ and Tier III- are

⁶*Aquila Remotely Piloted Vehicle—Its Potential Battlefield Contribution Still In Doubt*, GAO NSIAD-88-19, October 1987.

⁷*Unmanned Aerial Vehicles (UAV) Master Plan 1992*, DoD, 15 April 1992, pp. 6-8.

⁸*High Altitude Endurance Unmanned Aerial Vehicle Systems—Program Briefing for Joint Requirements Oversight Council*, 8 November 1994.

⁹*Unmanned Aerial Vehicles 1994 Master Plan*, DoD, 31 May 1994, p. 3-29.

also known as the CONV (conventional) HAE UAV and LO (low observable) HAE UAV systems, respectively.¹⁰

The evolution of these programs is depicted in Figure 5. In this report, we focus entirely on the Tier II+ program.

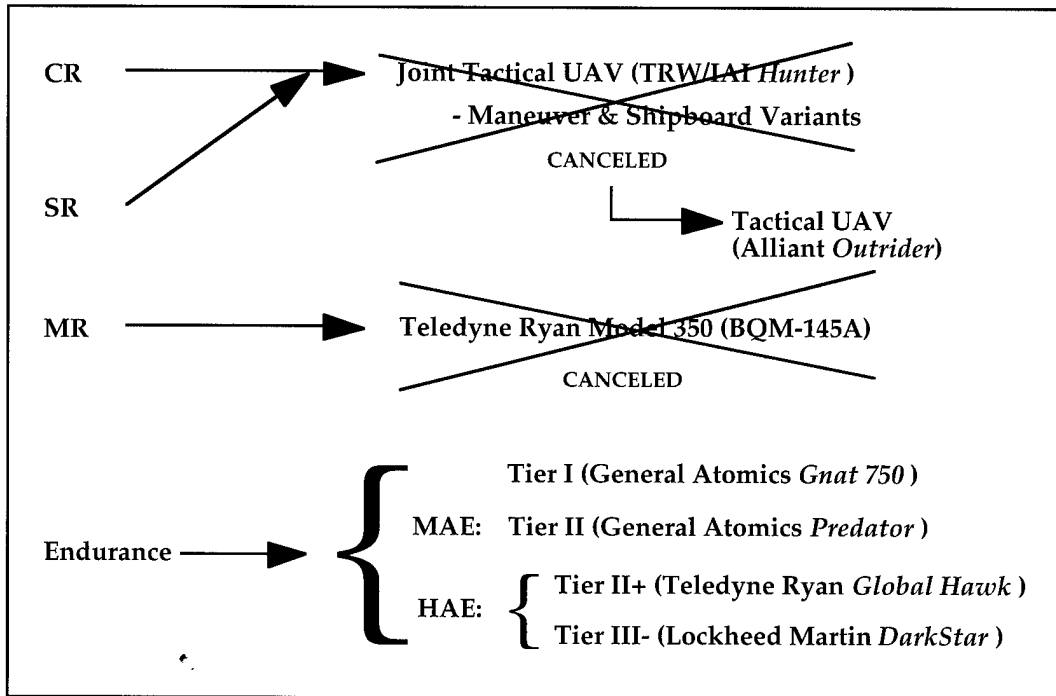


Figure 5—Recent UAV Program History

¹⁰High Altitude Endurance Unmanned Aerial Vehicle Systems—Program Briefing for Joint Requirements Oversight Council, 8 November 1994.

4. ADDRESSING THE ACQUISITION ISSUES

Since problems with UAVs were generally attributed to the acquisition process rather than to any inherent flaw in the UAV concept, the newer UAV programs became a logical target for acquisition reformers.¹ The specific set of reforms ultimately applied to the HAE UAV program, and the implementation of those reforms, evolved over a period of time. The overall objective of the reforms was to provide a higher assurance of conducting a “successful” program; one that led to the enhancement of operational capabilities in a way that was deemed by the users to be worth the cost. That global objective was addressed through four separate but related tactics:

- Create a highly streamlined management process to save time and money throughout the acquisition program.
- Apply a rigorous cap on production cost of the final weapon system.
- Utilize the ACTD approach to enable rapid and low-cost exploitation of the best available technology.
- Design for low overall program risk.

Each of these tactics is described below.

STREAMLINED PROGRAM MANAGEMENT

A major objective of the JPO was to structure the management process so as to make it as efficient as possible. Several strategies were used to satisfy that goal.

Simplified Product Specification

One part of that goal was accomplished through the strategy of specifying only one firm requirement: the UFP discussed above. Other desired performance characteristics were defined in terms of a range of values deemed acceptable, and the contractor was given the responsibility of finding a balance among the various performance parameters so that the overall system satisfied the user’s needs. This freed the JPO from the task of monitoring the contractor’s progress toward achieving a large number of individual performance specifications. In fact, at the beginning of the program the JPO did not have a clear and complete image of a total system concept, and hence had to rely on the contractor to produce such an image of a balanced system. The JPO tried hard to avoid giving signals that they

¹Although the CR UAV program was designated a Defense Acquisition Pilot Program (under Public Law 101-510, Section 809, Title 10, USC 2436) by 1992, the reorganization of the UAV JPO and the consolidation of CR and SR effectively rendered this decision moot. (*Unmanned Aerial Vehicles (UAV) Master Plan 1992*, DoD, 15 April 1992, p. 24.) When the Endurance program split into the Medium Altitude Endurance (MAE) UAV and the High Altitude Endurance (HAE) UAV, both of these were designated ACTDs. The HAE UAV was established as a DARPA program with DARO sponsorship, and a Joint Project Office was established outside the UAV JPO.

would value more of any particular performance goal very highly (more loiter time, etc.) and tried to force the contractor to select, and defend, a particular balance of capabilities.

Pilot Acquisition Provisions of Public Law

Another major element of the strategy to simplify the management process was to use provisions of recent legislation permitting removal of some oversight and management process strictures typically found in government acquisitions. The HAE UAV program has been designated a Pilot Acquisition program under the provisions of Public Law 101-189, Section 2371, Title 10, USC, and Section 845 of the 1994 National Defense Authorizations Act (Public Law 103-160). This allows DARPA to use an "agreement" in lieu of a contract, and permits the waiver of Federal Acquisition Regulations (FARs), the Defense FAR Supplement (DFARS), the Armed Services Procurement Act, the Competition in Contracting Act, and the Truth in Negotiations Act (TINA), in addition to releasing the contractor from military specification compliance. All procurement system regulations are inapplicable. It also frees the contractor from the need to undergo Defense Contract Auditing Agency (DCAA) audits, allowing instead the use of commercial auditors.

This authority is known as "Other Transactions Authority" or simply, "DARPA Agreements Authority." DARPA already had the authority (under Section 2371) to use "cooperative agreements and other transactions" to implement its dual-use projects that feature cost sharing with industry; a few dozen of these "nonprocurement" agreements had been implemented.² Section 845 expanded that authority to prototype projects that are directly relevant to weapons systems (i.e., those that are not dual use). HAE UAV is the first program to implement this Section 845 authority.

Note that these Pilot Acquisition waivers were initially granted to HAE UAV only through Phase II (strictly speaking, for a period of three years from the enactment of the act granting the waivers). The extension of the waivers into Phase III was not assured at the time of Phase I and represented significant uncertainty for the bidding contractors. Eventually, if the program transitions into Phase IV production, it may be necessary to bring the program back into the "standard" acquisition system. However, that system itself is undergoing metamorphosis, so little can be planned at this point.

It should be noted that two FAR clauses are retained in all DARPA agreements: Article XI, "Officials not to Benefit," and Article XII, "Civil Rights Act," are required by law. Key differences from a typical fixed-price contract include Article IV, "Payable Event Schedule" (parties can agree that payable milestones can be altered based on program events), and Article VII, "Disputes" (the DARPA director is the ultimate arbiter of disputes).³

²For a review of experience with some of the other projects, see M. S. Nash et al., *Participant Views of Advanced Research Projects Agency "Other Transactions,"* Institute for Defense Analyses Report D-1793, November 1995.

³This material is largely drawn from the *HAE UAV Industry Briefing* given by the JPO on 5 May 1994.

Integrated Product and Process Development

An additional feature of the Tier II+ program, as distinct from the Tier III-, is that the JPO strongly encouraged use of integrated product and process development (IPPD) and associated IPTs. While certainly not unique to this program, the heavy reliance on IPPD is a factor that must be considered when evaluating the effects of acquisition streamlining.⁴

IPPD is defined as a management technique that simultaneously integrates all essential acquisition activities through the use of multidisciplinary teams to optimize the design, manufacturing, and supportability processes. It is a concept that has grown out of the practice of "concurrent engineering" and was first implemented in DoD by the Air Force, which applied it to the F-22 program. On 10 May 1995, the Secretary of Defense directed that the concepts of IPPD and IPTs be applied to the acquisition process to the maximum extent practicable, in particular to the Office of the Secretary of Defense (OSD) oversight process.⁵

This has led to two distinct implementations of IPPD. In OSD, the "vertical" IPT is a replacement for the former time-consuming serial program-review process, which is characterized by meeting after meeting at ever higher levels. In the IPT mode, all decisionmakers are present at each meeting, and decisions are therefore expedited. IPPD implementation at the program level is different and more in keeping with industry practice. IPTs are formed in distinct product areas (which differ between programs) and are characterized by participants empowered and authorized to the maximum extent possible to make commitments for the functional area or organization they represent. Key personnel are involved at an early stage, and timely decisionmaking is encouraged.

Government program office personnel join contractor employees in IPTs, operating in an atmosphere of teamwork and mutual trust based on shared data. The government defines performance objectives rather than dictating product and processes and imposes minimum oversight consistent with stewardship of public funds.

One problem with assessing the results of IPPD is that implementations vary widely across different organizations. Since IPPD itself encourages the "tailoring" of IPTs to programs, IPPD has at times become a somewhat general concept, and thus it is difficult to analyze.

Regarding the implementation of IPPD in the HAE UAV program, although the stated intent of DARPA was to *encourage* firms to organize as integrated product teams rather than by functional discipline, in the Tier II+ program this took the form of a de facto mandate.

SMALL JPO STAFF

Consistent with the attempt to encourage the industry team members to organize and perform efficiently, the JPO itself was an austere organization. It is not possible to define the exact JPO staff level during Phase I because it fluctuated over time—specialists were

⁴The details of the UFP limit were finalized and the decision to implement IPPD was made during a series of trade-off studies and key meetings in the winter of 1994.

⁵Secretary of Defense William Perry, "Use of Integrated Product and Process Development and Integrated Product Teams in DoD Acquisition," letter dated 10 May 1995.

drawn in from various other agencies when needed. However, during most of Phase I it appears that the JPO staff consisted of a core of about a dozen people, plus about two dozen full-time equivalent specialists and support personnel. As will be noted later in the discussion of contractor interviews, there were a few periods when the JPO staff was stretched pretty thin trying to interact with five competitive industry teams, but the small staff was generally consistent with the minimal oversight imposed and the great degree of autonomy provided to the contractors.

UNIT FLYAWAY PRICE LIMIT

One of the prominent difficulties encountered by earlier UAV programs was that the cost tended to escalate so much during the acquisition phase that the resulting system cost more than the user was willing to pay. This pattern was typical of many systems developed during the past three or four decades, reflecting a clear preference by the developers to emphasize achievement of high levels of system performance, at the expense of cost.⁶

Several policy initiatives have been introduced from time to time in an attempt to control or mitigate cost growth during acquisition. During the 1960s and 1970s the notion of "design to cost" (DTC) was introduced. The basic notion behind DTC was "to set a cost goal very early on, similar to the way a performance goal is set, and then design to that goal."⁷ This approach was incorporated in DoD Directive (DODD) 5000.1 in July 1971 and was applied to some degree in many programs of the 1970s. However, the Institute for Defense Analyses study noted above found that the cost growth experienced in those programs was not significantly different from that of other programs, mainly because the overall acquisition management system was unwilling to make the sacrifices in system performance necessary to achieve the stated cost goals.

Another early initiative to control cost was the notion of fixed-price development, usually incorporated with the broader concept of total-package procurement. The few programs on which these policies were applied generally turned out badly, mainly because the initial development contract tried to define a set of system descriptors and performance specifications *and* a fixed cost requirement. Early estimates of that set of parameters were inevitably optimistic and could not be achieved in practice. The overall concept was quickly discredited.

A more recent initiative has focused on treating cost as an independent variable (CAIV). The argument is that the ultimate user of the system should play a stronger role in establishing the initial balance between cost and other system performance parameters, and that the established cost goal could be achieved through integration and strengthened implementation of existing DoD policies and processes. To our knowledge, no measurable experience has been accumulated under this policy that would permit evaluation of its effectiveness.

⁶Jeffrey A. Drezner, Jeanne M. Jarvaise, Ronald W. Hess, Paul G. Hough, and Daniel M. Norton, *An Analysis of Weapon System Cost Growth*, RAND, MR-291-AF, 1993.

⁷Karen W. Tyson et al., *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness*, Institute for Defense Analyses, Paper P-2201, March 1989.

It can be seen that the HAE UAV programs might be considered part of a long-standing effort to control acquisition cost. It is important to note, however, that the HAE UAV Program Office introduced a radically different, and potentially stronger, method for controlling cost by treating it as the *only* required program "deliverable," *with all other performance objectives subject to trade-offs to meet the price objective*.⁸ Following program initiation, but prior to the award of Phase I agreements, a \$10 million (FY94 dollars) UFP cap was imposed by Deputy Under Secretary of Defense, Advanced Technology (DUSD/AT) on both the Tier II+ and Tier III- programs. The degree of innovation that this approach represents can hardly be overstated. It is contrary to the established culture of acquisition management, where system performance has been the dominant criterion on which program success was based. Such a performance-dominated style has been well understood and practiced by both government and industry for several decades. Whether the HAE UAV JPO can be successful in breaking that strong cultural pattern remains to be seen.

ADVANCED CONCEPT TECHNOLOGY DEMONSTRATIONS

The ACTD process evolved in 1994 in response to recommendations of the Packard Commission (1986) and the DSB (1987, 1990, 1991).⁹ ACTD programs are intended to provide a means for rapid, cost-effective introduction of new capabilities into the military services. The core elements of the ACTD initiative were summarized by Dr. Kaminski, Under Secretary of Defense for Acquisition and Technology (USD(A&T)), as follows:

There are three characteristics . . . which are the hallmark of the program. The first is that there is usually joint service involvement in an ACTD. Second, ACTDs allow our warfighters to perform a very early operational assessment of a system concept before we've invested a lot of money in the concept. And third, there is usually some residual operational capability left in the field at the completion of an ACTD, even if we haven't decided to put the program into a full development phase.¹⁰

Approved ACTDs for FY95 and FY96 are listed in Table 1.

As integrating efforts intended to demonstrate a new military capability based on maturing advanced technologies, ACTDs must address user requirements clearly enough to firmly establish operational utility and system integrity. Demonstrations are jointly sponsored and implemented by operational users and materiel development communities, with approval and oversight guidance from the DUSD/AT. Figure 6 depicts the DUSD/AT ACTD approval process.

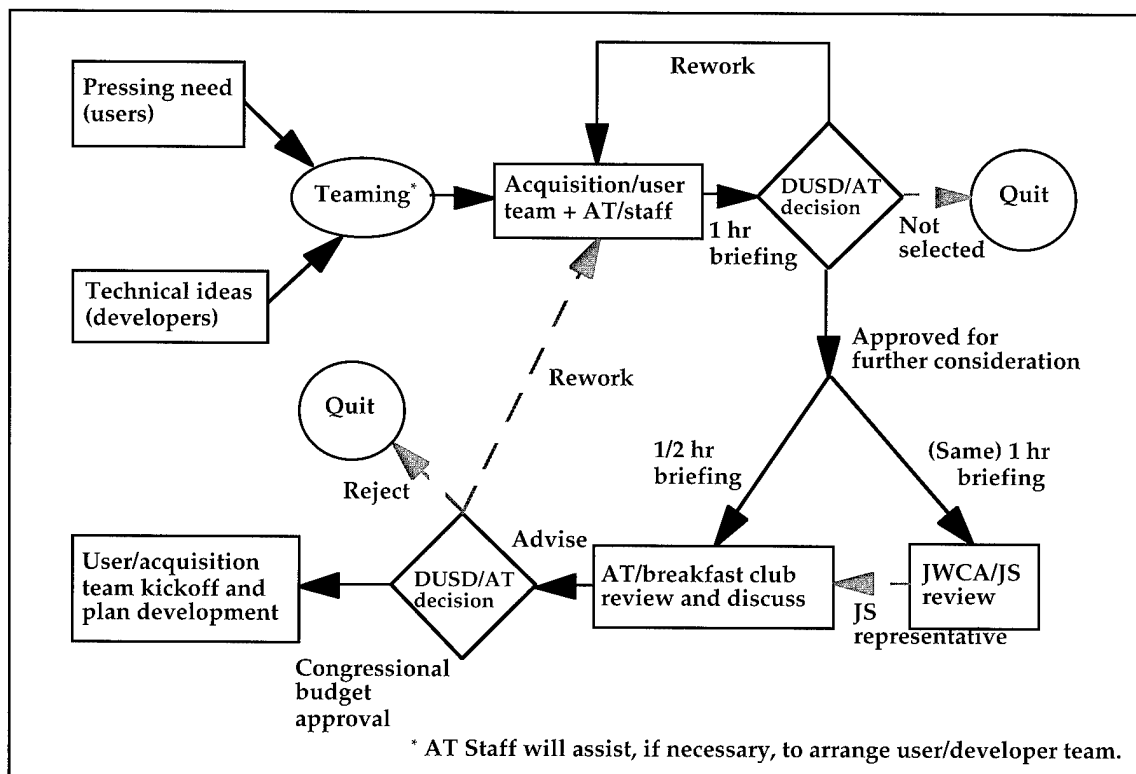
⁸The \$10 million UFP includes all flight hardware including airframe, avionics, sensors, communications, integration, and checkout and is to be the total price paid by the government including profit. Specifically, the UFP is defined as the average price for a Phase IV lot of 10 air vehicles, to be delivered over a 12-month period. Thus, the UFP limit is a projection, *not* a guarantee in the normal contractual sense.

⁹The material in this and the remaining paragraphs on ACTDs is drawn from the April 1995 *ACTD Master Plan* published by the DoD, and from a May 1995 summary by Hicks and Associates, Inc.

¹⁰DoD news briefing, 28 June 1995.

Table 1
Approved Advanced Concept Technology Demonstrations:
New Starts in FY95 and FY96

FY95	FY96
MAE UAV	Combat Identification
Precision SIGINT Targeting System	Total Asset Visibility
Joint Counter-Mine	Low Life Cycle Cost Medium Lift Helicopter
Cruise Missile Defense—Phase I	Semi-Automated Imagery Processing
Counter Multiple Rocket Launcher	Battlefield Awareness & Data Dissemination
HAE UAV	Counter Proliferation
Boost Phase Intercept	Military Operations in Built-up Areas
Rapid Force Projection/EFOG-M	Ship Defense vs. Imaging Infrared Missiles
Synthetic Theater of War	Navigation Warfare
Advanced Joint Planning	Miniature Air Launched Decoy
	Land Vehicle Survivability
	Biological Defense Net



SOURCE: DUSD/AT World Wide Web site, <http://www.acq.osd.mil/at/implement.html/>

Figure 6—DUSD/AT ACTD Approval Process

The entire ACTD process, including the selection and funding, is overseen by the ACTD Steering Group chaired by the Vice Chairman of the Joint Chiefs of Staff (VCJCS) and USD(A&T), with membership including service acquisition executives and military operations deputies. In addition, the selection of ACTDs is reviewed by the JROC through the Joint Warfare Capability Assessment (JWCA) groups.

The ACTD process is intended to stand alone from other, ongoing acquisition reform efforts. It is distinct from these efforts by virtue of its emphasis on heavy user involvement throughout the ACTD. Nevertheless, certain recent initiatives, such as the Secretary of Defense's decision to mandate the use of "vertical" IPTs as a substitute for the former time-consuming serial OSD review process, do attempt to mimic the streamlined ACTD management process.

The basic organization and acquisition strategy of the HAE UAV program evolved during the same time period that the ACTD process was being formulated, and there was close coordination between the principals of both activities during the 1993-1994 time period. Therefore, while the HAE UAV program was initiated (solicitation to industry for Phase I submissions) in April 1994, before the ACTD process was formally introduced, it was structured in a multiphase arrangement that was fully compatible with the ACTD process, and it was included in the list of projects that made up the initial ACTD portfolio. A formal Memorandum of Understanding (MOU) designating the HAE UAV program as an ACTD was issued in October 1994.

One major consequence of designating the HAE UAV program as an ACTD was that the program could be started without going through the very elaborate and time-consuming process required for typical Acquisition Category (ACAT) I and ACAT II programs as described in DODD 5000.1 and DoD Instruction 5000.2. Those traditional management procedures are based on the assumption that relatively large forces of the new system will be produced and employed in well-understood ways, thus justifying extensive front-end planning and coordination. An ACTD program, however, offers an opportunity for radically new system concepts to be developed through a process where operational employment tactics are developed along with the hardware, and the overall effectiveness of the system is not judged until operational trials. Thus, somewhat less front-end planning and coordination is demanded before program start, and critical decisions are pushed downstream to a point where demonstrated performance capabilities are available.

FY95 ACTDs were drawn from existing funded programs, and consequently, the OSD ACTD budget line provides only about 7 percent of their funding (\$200 million from a total acquisition budget of \$2.8 billion) through FY01. Hicks and Associates point out that each year, this fraction is likely to increase as the pool of prior-funded programs is depleted.

In one sense, then, the ACTD process represents a very small budget slice for OSD. Nevertheless, the power to initiate a program is not to be underestimated, given the notorious difficulty of canceling ongoing acquisitions. Consequently, Congress has shown some wariness on the subject of ACTDs—the FY95 Appropriations Conference insisted that "No new ACTD may begin without prior consultation with, and notification to, the Committees on Appropriations."¹¹ The HAE UAV program in particular has faced repeated congressional attempts to consolidate its two elements (Tier II+ and Tier III-).

Aside from the problem of the predicted increase in OSD's ACTD budget share, which may impel Congress to rein in the use of ACTDs, other features of ACTDs may result in

¹¹*Aerospace Daily*, 29 September 1994.

pitfalls: For example, although failure of a particular ACTD demonstration does not equate to failure of the ACTD concept, this is a distinction made by ACTD management that may not be appreciated by politicians and the public. Another potential problem is that the ACTD process has yet to be institutionalized, and early failures may imperil its adoption by future DoD management.

One note regarding the application of the ACTD process to UAV programs: The dearth of operational UAV experience makes the early and extensive involvement of operational users imperative. There is thus likely to be relatively high payoff to using ACTDs for such programs.

DESIGN FOR LOW PROGRAM RISK

Another management strategy, and one that was less clearly enunciated during the early parts of the program, was that the JPO tried to design a program with relatively low risk of serious failure. This, too, was a challenge because the traditional DARPA program has tended to emphasize high system-performance goals, while accepting the concomitant risk of technical failure. Instead, the JPO wanted this to be a low-risk program. More specifically, the office believed that a program carrying low technical risk equated to low risk of not achieving the UFP goal. One tactic used to achieve this goal was to convey a strong message that the development funds were limited to a specific amount, and that no more money would be available to the contractors, in the hopes that this would instill a bit of caution in the contractors' plans and actions. In retrospect, the office is not sure that message came through as clearly as it hoped. At least one contractor during Phase I clearly misinterpreted the JPO vision of how risks and other program objectives should be balanced.

The JPO did not try to develop a specific set of priorities among the major program goals (system performance versus UFP versus NRE versus risk of a major failure, etc.). In retrospect, an exercise along such lines might have helped to clarify some of the messages to the industry during Phase I.

The desire for low overall program risk had a major consequence when the funding was cut early in Phase II. In that circumstance, a traditional approach might have been to retain both contractors in a competitive environment and save money by reducing the amount of system maturity desired at the beginning of the Phase III operational test phase. However, the possibility of an unsuccessful operational test because of system development deficiencies was judged too great, and the funding cut was accommodated by eliminating one of the competitive contractors during Phase II.

HAE UAV ACQUISITION STRATEGIES IN THE CONTEXT OF OTHER UAV PROGRAMS

These strategies for improving the HAE UAV acquisition process, while not unique to HAE UAV, have never before been combined in one program. The differences among the two

HAE UAV programs, the *Predator* MAE UAV, and a representative program conducted under the established acquisition system (the canceled MR UAV) are summarized in Table 2.

Table 2
UAV Programs—Acquisition Differences

	HAE Tier II+	HAE Tier III-	MAE Tier II	MR
ACTD	Yes	Yes	Yes	No
Pilot acquisition (Section 845)	Yes (Phases I, II) TBD (Phases III, IV)	Yes (Phases I, II) TBD (Phases III, IV)	No	No
UFP limit	No (Phases I–III)	No (Phases I–III)	No	No
	Yes (Phase IV)	Yes (Phase IV)		
IPPD	Yes	No	No	No
Contract type	Phase I: FFP Phase II: CPIF/CPFF Phase III: FFP (Agreement)	Phase II: CPIF/CPFF Phase III: FFP (Agreement)	CPFF (Contract)	FFP (Contract)
Competition	Phases I, II: Yes Phases III, IV: TBD	No	Yes	Yes
Other features	High Altitude	LO design, Special access	Derivative	High speed Air launched

5. INFERENCES FROM CONTRACTOR INTERVIEWS

Initial Tier II+ interviews were conducted with the contractors listed in Table 3. These included all but one of the Tier II+ Phase I prime contractors, selected Phase I subcontractors, and a representative unsuccessful Phase I bidder (Aurora Flight Sciences).

The primary purpose of these Phase I interviews was to increase confidence in the eventual results of the HAE UAV case study, by enabling generalization of "lessons learned" across a range of company structures and sizes, and across a range of potential acquisition programs. We hoped to capture the diversity of contractor experiences during the program's formative phase, thereby identifying preferred strategies and potential pitfalls.

Each of the interviewed contractors was asked to comment on their perceptions and experiences in relation to the key features of the Tier II+ program. They were then asked to comment on the nature of their interaction with the JPO and to identify any residual effects on their organizations as a result of having participated in the program.

CONTRACTOR PERCEPTIONS OF ACTD

The contractors had some misgivings about whether there was adequate high-level user support, but user involvement was deemed to be adequate at the working level. There was some concern expressed about the institutionalization of the ACTD process in the future, however.

With respect to the program schedule, which is driven by the ACTD format, there was uniform agreement that the schedule was "ambitious, but doable." In other words, the schedule is success-oriented. There was particular concern expressed about the overlap between Phase II flight testing and the ordering of Phase III long-lead items, along with the expressed intent of DUSD/AT to avoid any development in Phase III.

Table 3
Contractors Interviewed

Orbital Sciences Corporation	18 July 1995
Aurora Flight Sciences	20 July 1995
Northrop Grumman	21 July 1995
Boeing	3 August 1995
Raytheon	7 August 1995
Westinghouse	9 August 1995
Scaled Composites	28 August 1995
Teledyne Ryan	13 September 1995
E-Systems	22 September 1995
Loral	Declined to participate
Frontier Systems	Loral team, thus not interviewed

There were also misgivings about the Phase IV transition to production, stemming from uncertainty about Phase IV requirements. In some quarters, the need for Phase IV itself was questioned, given the likely production totals for a system like Tier II+. Thus, it will likely make sense to buy as many systems in Phase III as will be required operationally, rather than productionizing the design for only a few more units.

To show how the threat of future additional requirements burdens the program, even the planned transition of the program to a WPAFB System Program Office for Phase III is cause for trepidation. There is a feeling that a USAF System Program Office will be wedded to "business as usual."

In summary, there is uniformly strong support for the concept of ACTDs, but concern about the future in terms of potential added requirements, and the possibility of a schedule disruption due to high concurrency of development and "production."

CONTRACTOR PERCEPTIONS OF IPPD

To an almost uniform degree, the "encouraged" implementation of IPPD had a net neutral effect on the contractors. In most cases, the contractors had previous favorable experience with either IPPD or what they perceived to be its equivalent. Consequently, they asserted that they would have organized around IPTs in any event.

The participation of the JPO in the IPTs during Phase I was more controversial, however. While the core JPO staff was uniformly praised, and all felt that DARPA was the best host for the JPO, there were some problems in execution. A lot of problems stemmed from the JPO decision to award five instead of three Phase I agreements, which led to severe overwork for the JPO, and a consequent perception by the contractors that there was insufficient interaction, or dialog, with the JPO.

It was also clear to the contractors that the government staff on temporary assignment to the JPO were in many cases not attuned to the unique circumstances of the program. There was a tendency on the part of these personnel to conduct "business as usual," an inclination that the JPO was not always successful in countering. The contractors also perceived implicit direction from the government at times. Again, the overwork of the core JPO staff probably aggravated this problem.

A different criticism related to the dichotomy between competition and teaming. A common comment was that the JPO was slow in appreciating that the ongoing competition imposed constraints on its ability to function as a full IPT member with each contractor. There was general agreement that the JPO engaged in "leveling" during Phase I (taking the best ideas from each contractor and incorporating them in subsequent requirements); but the contractors were generally unconcerned about this, seeing a benefit as well as a loss.

In summary, where JPO performance fell short of expectations, it was seen to be a result of a flaw in execution rather than concept, stemming in large part from the early decision to make five Phase I awards. (The surprise decision to down-select to only one Phase II contractor was also roundly criticized.) Whether full government participation in contractor IPTs is appropriate during a competitive phase remains a difficult question, however.

CONTRACTOR PERCEPTIONS OF \$10 MILLION UFP CAP

All contractors felt that the \$10 million UFP cap was a reasonable value and strongly supported the design-to-price philosophy. There was general success in securing fixed-price vendor quotes: The industry believed that the UFP cap was real and proposed accordingly.

There were clear differences of opinion regarding the relationships among different kinds of risks in the Tier II+ program. One camp argued that a design approach with very low technical risk will result in a relatively large flight vehicle, leading to higher production costs and therefore increased risk of not meeting the UFP cap. Since the JPO clearly stated that the UFP cap must be met, that theory apparently led some contractors to accept somewhat higher technical risks to achieve flight vehicle designs that were smaller, lighter, and thus (presumably) less expensive to produce.

An alternative theory held that designs incorporating considerable innovation, and hence higher technical risk, inevitably led to relatively more uncertainty over the eventual production cost, thus raising overall program risk. Adherents to that theory further argued that a design based on fully demonstrated technologies and components would lead to a production cost estimate that could be made with great confidence. If that production cost estimate was within the specified UFP cap, then the "conventional" (i.e., low-technical-risk) design approach also yielded the lowest UFP risk.

There is no evidence that the different concepts of risk evaluation were ever resolved, or even clearly articulated and debated, during Phase I. What does seem clear is that each theory had its adherents among the contractors both before and during Phase I, while the source selection strongly suggests that the JPO tended to favor the second approach, equating lower technical risk to lower overall program risk, including lower risk of not meeting the UFP cap. Thus it appears that the emphasis placed by the JPO on meeting the UFP did not send an unambiguous signal to the industry regarding a preferred strategy for managing overall program risk.

Most contractors believed that Teledyne Ryan's bid entailed high cost risk; there was a common perception that there was a serious lack of UFP accountability downstream, and there was much skepticism regarding competitors' UFPs. Line drawings of the five Tier II+ Phase I contractor design concepts were unexpectedly published in an aerospace trade publication in late 1994, along with gross take-off weight and wing span data.¹ The 2:1 range of gross weight values was surprising for aircraft that were supposedly of equal cost. Hence, it was logical to suspect each other's cost methodology and the JPO's cost assessment capability. (It has been pointed out by the JPO that the *empty weights* of the five designs did not vary by as much, and that the weights converged as Phase I progressed; nevertheless, that information was presumably not available to the contractors.)

The NRE limit was seen as more challenging than UFP by most contractors. UFP-NRE trades were conducted informally, although there was some suggestion that in future programs, the government should elevate NRE to the same level of attention as was lavished on UFP.

¹*Inside the Pentagon*, 13 October 1994, pp. 10-12.

Most contractors were pessimistic about the ability of the program to keep future costs under control. Few expected the \$10 million UFP cap to last. The reasons for this pessimism varied. Some felt that the elimination of competition for Phase II and beyond severely impacted cost credibility. Some were concerned about the uncertainty of future continuation of ACTD and acquisition streamlining privileges. Some anticipated requirements growth and configuration changes. Some flatly disbelieved Teledyne Ryan's cost estimates.

CONTRACTOR PERCEPTIONS OF ACQUISITION WAIVERS (SECTION 845)

Not unexpectedly, there was unanimity about the beneficial effects of the Section 845 acquisition waivers. What was surprising was the freedom granted by corporate management to the respective Tier II+ teams, as a synergistic result. Uniformly, top management appreciated that "reinventing government" and reinventing corporate culture go hand in hand. A new "paradigm" was recognized. This was probably accentuated by the organizational mirroring that occurred between the JPO's organization and that of the contractors (in this sense, there may be an interaction with the IPPD effect).

It was common that internal corporate procedures and requirements were waived, even when not specifically a result of waived government requirements. Contractors took advantage of waivers to establish new strategic directions and to overcome internal organizational hurdles. Streamlined contractor organizations were set up, with reduced overhead and general and administrative rates, sometimes physically isolated from the parent organization, sometimes not. "Skunk works" was often used as a metaphor, but the value of the parent organization for manpower leveling and administrative support was recognized. In some cases, the impact of the Tier II+ program outlasted the contractor's involvement in the program—the new business unit was retained for future projects.

Some contractors would not have even bid without the acquisition waivers—others would have bid, but at a significantly higher cost. It was clear that the waivers had a major effect in reducing the "barriers to entry" perceived by the contractors. It was also asserted that the success of the ACTD process will depend critically on having acquisition waivers in place. Of course, this has not yet been tested.

The relative benefits of the waivers granted regarding the Competition in Contracting Act, the Contract Data Requirements List, military standards/military specifications, and cost accounting were emphasized to varying degrees by each contractor.

INTERVIEW SUMMARY

The most striking aspect of the Tier II+ Phase I contractor interviews was the wide agreement on most aspects of the program. Despite the forthright criticisms, which related mostly to specifics of program execution, there was universal support for what the JPO was trying to achieve. It is clear that each of the special features of the Tier II+ program played a key part in guiding the contractors' decisionmaking processes, and it is also clear that the special features are heavily interrelated.

For the future, the level of agreement displayed by the Tier II+ Phase I contractors on the effects (or predicted effects) of the program's special features leads us to believe that the

experiences of the Teledyne Ryan contractor team will be more generalizable than would otherwise have been the case.

Table 4 is our interpretation of the *contractors' perceptions* of the four special features of Tier II+, relating to both concept and execution (the scale being poor/OK/good/very good). Note that the "poor" comment on UFP relates to the perceived primacy of low technical risk over low UFP risk on the part of the JPO. Since losing contractors generally ascribed their loss to technical (or performance or programmatic) risk, this is possibly a biased result.

Table 4
Contractors' Perceptions of Phase I

	Concept	Execution
ACTD	Good	OK
IPPD	OK	OK
UFP	Good	Poor
Waivers	Very good	Very good

Appendix A

TIER II+ MISSION DESCRIPTION AND PRELIMINARY CONCEPT OF OPERATIONS¹

The Tier II+ system is to provide long-dwell, wide-area, highly responsive coverage of areas of interest to a joint task force (JTF) commander. The system should be able to cover very large areas day or night, in adverse weather conditions; it should be possible to provide the coverage requested very rapidly and in a form that can be readily used. Lessons learned from imaging radar systems and EO sensor technology should permit a low-risk, multisensor system capability.

The system is to operate from extended range and employ SAR, EO, and IR sensors to collect imagery on point targets and broad geographic areas. The system will provide deep-look, on-demand access to critical targets and frequent revisit, and, when required, near-continuous surveillance of specific, high-value objectives. Data are to be transmitted from the platform via satellite or via line of sight to a ground processing segment. That segment will be able to process, reformat, and disseminate the data in formats compatible with the primary dissemination and exploitation systems that support joint intelligence centers or are otherwise fielded by DoD.

THREAT

A threat warning system is to enable operators to identify and avoid potential SAM threats while planning mission tracks or by dynamic (real-time) changes to the flight path. The operational concept does not envision a risk-free environment. There will be situations in which some attrition will be expected.

In the *standard mission profile*, the UAV is to take off, climb to 50,000 ft within 200 nm, cruise to 65,000 ft and to the mission performance area at operating range, loiter there, fly back to the recovery area, and land.

PLATFORM BASING AND OPERATIONS

The system is to be land-based within range of anticipated objectives, host nations permitting. The aircraft and ground segment will be deployable by C-141. When the UAV is based within its operating radius of 1,000 to 3,000 nm, it will be able to spend up to 24 hours on station. A system of four aircraft and one ground segment should be able to continuously cover a major regional crisis area for 30 days. When it cannot be based forward, the UAV may have to fly more extended ranges, and continuous coverage would be reduced. Tier II+ is intended to operate in both standoff and penetration missions.

¹This appendix is condensed from the Tier II+ Phase I solicitation, ARPA PS 94-33, dated 1 June 1994.

COMMAND AND CONTROL

Duplex continuous command and control of the vehicle is to be supported via low-data-rate ultra-high frequency satellite communications. This link will provide the initial mission plan, dynamically update it during flight, and monitor the health and status of all systems. The UAV is to take off, fly, and land automatically. It should be possible to command the vehicle from any location in the world. The ground segment will plan the mission. It will receive prioritized collection requirements from the theater-designated collection management authority and will integrate them into the vehicle's mission plan.

SENSOR OPERATIONS

System sensor data are to be provided directly to the JTF. The collection manager will construct the mission collection plan so as to emphasize SAR strip and spotlight mode collection when the weather is not expected to be clear, and the EO/IR high-resolution sensor when it is. Ground moving-target indicator mode will be employed when information about hostile-force movement is one of the commander's priorities. The concept of operations envisions transmission of sensor data following collection and some onboard processing.

PREDEPLOYMENT OPERATIONAL SCENARIO

It is intended that the system support the information needs of the operational commander before combat forces or ground processing capabilities have been deployed. The system could cover key objective areas as well as critical point targets to meet a wide range of requirements such as situation monitoring and intelligence preparation of the battlefield. Because of the ranges involved and the lack of deployed assets, satellite communications are the key to success in this scenario.

In *regional-crisis (limited-deployment) scenarios*, only a limited force package is deployed. Tier II+ should be able to support the information needs of the JTF commander even though ground processing and exploitation assets are not forward.

In *wartime full-deployment scenarios*, the system's unique range and endurance capabilities should complement other national capabilities, manned airborne systems, and other UAV systems. Its roles would include urgent target location and identification, mission planning and rehearsal support, warning of imminent attack on U.S. forces or interests, comprehensive monitoring of forces, and battle damage assessment. Seamless interface with any of DoD's deployable processing and exploitation systems is paramount. Line-of-sight communications may be sufficient within the theater, but satellite communications will still play a large role because of the quantity of data.

Appendix B

TIER II+ PHASE I CONTRACTOR EVALUATION FACTORS¹

DARPA awarded multiple agreements for Phase I of the Tier II+ program. The selected contractors were to perform through the PSSR, after which DARPA anticipated down-selecting to two contractors at the end of Phase I. Prior to each of the Phase II and III down-select, each offeror was to be provided updated evaluation factors (see Appendix C). Additionally, each offeror was to be required to submit updated cost proposals for each phase. During or at the end of Phase II, the government planned to select one contractor to enter Phase III. Actually, however, down-selection to one contractor occurred at the end of Phase I. Each offeror's proposal received an integrated evaluation by a multifunctional team.

Three specific areas of evaluation were to be used for each program phase:

- Product capability.
- Program structure.
- Cost.

All areas were equally ranked according to the following assessment criteria:

- *Soundness of Approach:* Solicitation responses were to be evaluated from the standpoint of sound technical and management practices and the offerors' proposed approaches. Cost responses were to be evaluated to see that sound estimating methodologies and practices were used and that the costs presented completely described the program, were realistic based on the scope of effort, and defined all portions of the program.
- *Understanding the Program:* Solicitation responses were to be evaluated to ensure the offerors comprehended the scope of effort and the program objectives—specifically, for Phase I, the program objectives and the SCD. Cost responses were to be evaluated to determine if the funding levels they reflected completely captured all program objectives and were reasonable within the context of the total program.
- *Meeting the Objectives:* Solicitation responses were to be assessed to ensure that the offerors' approaches provided the most product utility while attempting to satisfy the provisions of the SCD and meet the \$10 million UFP. The cost responses were evaluated to ensure that the air vehicle UFP was completely covered and that the remainder of the program recurring and nonrecurring costs were completely and realistically stated.

¹This appendix is condensed from the Tier II+ Phase I solicitation, ARPA PS 94-33, dated 1 June 1994.

- *Past Performance:* The offerors' past performance in similar programs was evaluated to determine their suitability to develop and field the Tier II+ system. During the Phase I source selection, an integrated multifunctional team made a performance risk assessment based on past performance on other programs to determine each offeror's probability of completing the Tier II+ program. For the down-select, a multifunctional team assessed each offeror's performance during Phase I and made a performance risk assessment to determine which offerors had the highest probability of successfully executing Phase II. A performance risk assessment is to be made during the selection for Phase III.

The specific scope of evaluation within each of the areas of evaluation—product capability, program structure, and cost—were to be different for each phase as a result of the maturity of program data.

- *Product Capability:* The Phase I evaluation was to focus on the offerors' proposed system specifications as they related to the objectives outlined in the DARPA SCD. Additionally, the plan to mature the system as reflected in the offerors' IMPs was to be evaluated and risk determined. The Integrated Master Schedules (IMSs) submitted with the solicitation responses were also to be evaluated to determine if appropriate time and understanding of the program were in evidence. The Task Description Document (TDD) was to be evaluated to determine if all tasks were to be completed.
- *Program Structure:* The evaluation was to focus on each offeror's IMP, IMS, TDD, and the tracking system requested in the TDD. The integrated management system was an important evaluation element of the documents listed above. The systems engineering approach was also to be a key factor in this evaluation area.
- *Cost:* The evaluation was to focus on each offeror's realism, reasonableness, and completeness. The specific process the offeror used to integrate the design manufacturing and systems engineering to achieve a \$10 million UFP was also to be evaluated.

Appendix C

TIER II+ PHASE II CONTRACTOR EVALUATION FACTORS¹

DARPA examined the offeror's proposal for Phase II in the following areas.

SYSTEM CAPABILITY

Four basic questions were answered within the context of the \$10 million UFP:

- How close is the proposed system to meeting the SCD objectives? The preliminary system specification and system segment specifications were examined. The primary focus was on the final system configuration proposed for Phase III and the technical risk associated with achieving it.
- How effective and suitable will the final system be, as a whole, in the operational environment? DARPA subjectively and collectively evaluated the proposed system to determine if it possessed the performance features and capability necessary to accomplish the missions described in the Draft Concept of Operations.
- How stable is the proposed design and technical approach throughout the phases of the program? The degree of design maturity the offeror proposed for the end of Phase II was assessed. An estimate was made of the technical risk associated with the transition from Phase II through Phase III.
- How well does the system design support growth and flexibility? The proposed designs were analyzed to determine inherent growth capacity or design margin. DARPA also determined the adaptability of the proposed design to other similar missions.

TECHNICAL APPROACH

DARPA considered the structure of the technical program, progress made through Phase I, the technical effort and risk associated with completing the proposed system design, and meeting the \$10 million UFP. Low-risk technical approaches and maximum use of off-the-shelf technology were desired. Questions considered were as follows:

- Does the technical approach and IMP encompass the entire system? DARPA examined the proposal to determine if all proposed system features were adequately defined. The focus was on the degree to which each would attain an appropriate level of maturity by the events described.

¹This appendix is adapted and abbreviated somewhat from "Scope of Evaluation" in Section 8 of the Tier II+ Phase 2 solicitation (or "Selection Process Document"), dated 15 February 1995.

- Is the design, development, and manufacturing approach adequate for each phase of the program? DARPA assessed the plan to see if tasks and criteria provided a road map to the successful phase-by-phase maturation of the entire system.
- Are the technical processes described in the Process IMP adequate for their intended use? DARPA analyzed processes such as test, interface control, software engineering, and system support.

MANAGEMENT APPROACH

Here, the objective was to determine the degree to which the integrated management framework depicted a well-planned, easily trackable program and proposed a system deliverable within the resources provided. The evaluation addressed the following:

- *Planning.* DARPA analyzed the traceability of the task description document to the Product IMP and IMS, the viability of the program described in the Product IMP, the reasonableness and completeness of the IMS, and the integration of resources within the IMP and IMS.
- *Processes.* DARPA analyzed the Process IMP to determine the adequacy of the approaches and procedures applied to the program.
- *Program Control.* DARPA evaluated the financial management “tool set” applied to the program. Specific aspects considered were earned-value management and reporting, financial and budget-reporting systems, and integration of the IMS and the financial system.
- *Organization.* DARPA evaluated the offeror’s proposed IPT structure to ensure that teams were formally empowered and had been allocated resources commensurate with their authority and responsibility.
- *Past Performance.* DARPA evaluated the progress and execution of Phase I. Specifically, evaluators analyzed management style, ability to execute the plan, and acceptance and practice of integrated product development principles.

FINANCIAL APPROACH

DARPA assessed the ability of the offeror to execute the proposed program with the financial resources proposed and to achieve the required UFP. The financial resources were analyzed for each phase of the program and for the UFP allocation. DARPA used the following criteria:

- *Reasonableness.* To be considered reasonable, it was desired that the offeror’s cost estimate be developed from applicable historic cost data and be fully supportable with all assumptions, learning curves, equations, estimating relationships, etc., clearly stated, valid, and suitable.
- *Completeness.* DARPA evaluated the degree to which the offerors provided all cost information requested in the solicitation, how well all cost data were traceable and reconcilable, and substantiation of cost (i.e., supporting data and estimating rationale) for all cost elements.

- *Realism.* Estimates were considered realistic when they were neither excessive nor insufficient for the effort to be accomplished. Determination was made by comparing proposed costs with cost-estimating relationships, comparable data, government estimates, proposals of other offerors, etc.
- *Agreement.* DARPA evaluated the proposed agreement type and incentive structure to determine if they provide for an equitable sharing of risk between the government and industry, motivation of technical process and resource management, and adequate protection of public funds.